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THE RESULTS FROM A STUDY ON THE IMPORTANCE OF WEAPON SYSTEM SUPPORT TO DESIGN MANAGERS AND ENGINEERS

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THESIS

THE RESULTS FROM A STUDY ON
THE IMPORTANCE OF WEAPON SYSTEM
SUPPORT TO DESIGN MANAGERS AND ENGINEERS

by

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The Importance Of Weapon System
Support To Design Managers And Engineers

by

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ABSTRACT

It is hypothesized that in the aggregate design managers and engineers do not view product support as being of the same importance as production cost, performance, and schedule in their design of military systems/equipments. The results of a study to determine if this is true are set forth, and the implications of the results are discussed as they relate to the Navy's policy on Integrated Logistic Support.

TABLE OF CONTENTS

I. INTRODUCTION

Weapon system support has acquired considerable importance with the Deputy Secretary of Defense, the Chief of Naval Operations, and the Chief of Naval Material. The Deputy Secretary of Defense has stated in DoD Directive 4100.35 the following: "Over the life cycle of a system, support represents a major portion of the total cost and is sometimes the principal cost item."[1] In the foreword to NAVMAT Instruction 4000.20A, the Chief of Naval Operations and the Chief of Naval Material in a joint statement put forth the following policy: "Voids in support cannot be tolerated when every ship, every aircraft, and every weapon is essential to maintain the minimum level of Naval power necessary to meet American commitments throughout the world."[2] And weapon system support will also be, if it is not already, very important to defense contractors because of the following statement of the Deputy Secretary of Defense in DoD Directive 4100.35: "Contractor performance in carrying out the logistic support approach shall be a major factor in the evaluation of his performance of the contract as a whole."[3] The recognition by the military of the importance of weapon system support has led to the introduction of the Integrated Logistic Support Concept.

Integrated Logistic Support was introduced with DoD Directive 4100.35, "Development of Integrated Logistic Support for Systems and Equipments,"

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[1] Department of Defense Directive 4100.35, Development of Integrated Logistic Support for Systems/Equipments, p. 3, 1 October 1970

[2] Naval Material Command Instruction 4000.20A, Integrated Logistic Support Planning Policy, Foreword, 18 March 1971

[3] Department of Defense Directive 4100.35, Development of Integrated Logistic Support for Systems/Equipments, p. 6, 1 October 1970

on June 19, 1964. This Directive, which was revised and reissued on October 1, 1970, has been expanded upon and implemented within the Navy by NAVMAT Instruction 4000.20A, "Integrated Logistic Support Planning Policy," of March 18, 1971.

The policies and principles set forth in these two documents emphasized the relationship that design has with an effective integrated logistic program as indicated by the following excerpts:

1. "...logistic support considerations must have a meaningful relationship to design..."[4]

2. "Design of all operational systems shall take into account the aspects of logistic support."[5]

3. "The operational environment and the logistic support requirements which are the result, will be addressed during the trade-off stage of the system design process."[6]

4. "The Integrated Logistic Support System Concept is characterized by: The total integration of logistic design...with the hardware design."[7]

5. "Integrated Logistic Support requires that hardware design be reviewed with a view toward establishing hardware design and configuration which reduces, to the maximum practicable extent, the logistic support burden placed on the operating forces."[8]

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[4]Department of Defense Directive 4100.35, <u>Development of Integrated Logistic Support for Systems/Equipments</u>, p. 3, 1 October 1970

[5]Ibid., p. 3

[6]Ibid., p. 5

[7]Naval Material Command Instruction 4000.20A, <u>Integrated Logistic Support Planning Policy</u>, p. 1, 18 March 1971

[8]Ibid., p. 2

6. "Logistics requirements, where possible, will be quantified in a "design to" fashion."[9]

7. "The objective of early logistic support planning is the establishment of end item design and configuration characteristics which reduce, if possible eliminate, the need for logistic support resources."[10]

It can be concluded that the Department of Defense policy recognizes that design managers and engineers are "in the strongest position to force logistics decisions."[11] Therefore, the question posed to the author was: In the aggregate, do design managers and engineers understand and accept the fact that the cost and adequacy of logistic support is a matter equal in importance to the cost and adequacy of the end item of hardware itself?

This question was the basis for the formulation and testing of the following hypothesis: Managers and engineers involved in the design of military products do not attach the same importance to product support as they do to the production cost, the performance, and the schedule.

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[9] Naval Material Command Instruction 4000.20A, Integrated Logistic Support Planning Policy, p. 6, 18 March 1971

[10] Ibid., p. 6

[11] Dordick, H. S., The Designer's Impact on Logistics, paper presented at Department of Defense Logistics Research Conference, Warrenton, Virginia, p. 1, 26-28 May 1965

II. METHODOLOGY

The objective of the study was to gather sufficient data so that a statistically meaningful rejection or acceptance of the previously stated hypothesis could be made. The methods considered to be adequate for the gathering of this data were personal interviews and a questionnaire. But the time and funds available dictated the use of a questionnaire only. Such a questionnaire, Appendix A, was constructed. It was designed upon two basic premises: 1. A one page questionnaire with questions that required minimum reading and short answers; and 2. The survey results were to be general in nature so as to indicate if a more extensive questionnaire and/or personal interview survey would be warranted. The questionnaire was tested for ambiguities and format upon several Engineering Duty Officers at the Naval Postgraduate School and five design engineers of Lockheed Aircraft Corporation in Sunnyvale, California. From this test it was determined that the questionnaire was interpreted and answered in the intended manner.

Question one was intended to determine the respondent's present position in the design community and to identify the responses from individuals who were then employed outside of design. It was planned to exclude the latter group from the data base, for it was assumed that they would not reflect the design attitudes prevalent at the time of the survey, as was desired. The data from this question were used to determine if the attitudes expressed in question eleven depended upon a respondent's present position in the design community.

Questions two, three, and four were used to determine a respondent's work experience level. The data were employed to ascertain whether a

relationship existed between work experience levels and the military product support attitude specified in question eleven.

Questions five, six, and seven were included to identify the respondent's formal educational background. The data were used to determine if a relationship existed between formal education and the military product support attitude.

Questions eight, nine and ten were used to identify and eliminate from the data base those respondents who had had no experience in the design of products within the particular field in question (i.e., military, industrial, or consumer).

Questions eleven, twelve, and thirteen were respectively aimed at determining design attitudes of the respondent toward military, industrial, and consumer products. Each question requested the ranking of the same four elements. These four elements were defined within the questionnaire as follows:

1. "Cost - The direct cost (labor & material) required for the manufacture of a product." This definition of cost was used, because it expresses cost in terms of the significant cost elements that determine the production cost of a product. Therefore, in this survey "cost" was assumed to be synonomous with production cost.

2. "Product Support - The ease and economy with which a product can be repaired or maintained." The term product support was used, instead of either logistic support or integrated logistic support, so that the term would apply to all products whether they be military, industrial, or consumer. The definition of product support was couched in terms of product maintainability (i.e., ease was assumed to be interpreted by respondents as the time for repair or maintenance of a product, and economy was assumed to be interpreted as the cost involved with the maintenance or

repair). It was assumed that the concept of maintainability was basic and elementary to the overall concept of product support.

3. "Performance - The degree to which a product meets or exceeds specifications." This definition was assumed to be an easily understood and widely accepted definition.

4. "Schedule - The time allotted to complete the design of a product." "Schedule" was included in the four elements, for it was assumed that the time available for the design of a product would be of importance to the design manager or engineer in question.

The validity of these definitions was demonstrated with the previously mentioned test sample, in which all participants interpreted the definitions as intended by the questionnaire design.

The data from question eleven, which asked for attitudes toward the design of military products, were used to test the hypothesis of this survey.

The data from questions twelve and thirteen, which respectively asked for attitudes toward the design of industrial and consumer products, were employed to determine if there was a difference between the design attitudes toward a product for one customer (e.g., military) and a product for another customer (e.g., consumer or industry).

The sources solicited for the required data were selected from a list of the top seventy-four Navy contractors, in dollar volume, for fiscal year 1972.[12] From this initial list of seventy-four contractors, all steamship lines, universities, and governmental agencies were eliminated, for it was assumed that they employed very few, if any, design personnel.

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[12] Naval Material Command P-2400, Survey of Procurement Statistics, p. 48-50, June 1972

Based upon the following criteria, this list was reduced to the thirty-seven companies which received questionnaires: 1. Total sales in excess of one hundred million dollars; 2. Employees in excess of ten thousand; and 3. Products which would require the services of design personnel. In seven instances a company's industrial or consumer division was surveyed instead of its military division. This was done to increase the probability of having the sample contain individuals with industrial and consumer design experience. A cover letter, Appendix B, and ten questionnaires with self-addressed return envelopes were sent to each company. The cover letter requested that the questionnaires be distributed randomly to design managers and engineers and returned anonomously by them.

The survey methodology, which has been outlined above, was recognized to have several strengths and weaknesses. Among the strengths were: 1. The design managers and engineers who comprised the survey sample represented thirty-seven companies whose combined sales to the Navy in fiscal year 1972 represented fifty-two percent of the Navy's total procurement dollars; 2. The anonymity given to the companies and their design personnel helped to reduce a biasing influence; 3. The cover letter requesting a company's participation, and the questionnaire itself, did not indicate that the survey was being undertaken to determine the importance attached to product support by design managers and engineers. Therefore, any biasing influence resulting from a knowledge of the intention of the survey was eliminated; and 4. An expected number of responses in excess of one hundred increased the probability that the attitudes of the sample would be representative of the total population of design managers and engineers.

Among the weaknesses were: 1. The failure and/or inability to guarantee that the sample of design managers and engineers was a random sample;

2. The failure and/or inability to determine with what specific products or under what type of contracts the respondent had had his design experience. These factors by themselves could possibly determine or change the attitudes of a design manager or engineer (i.e., a respondent's attitudes could be very flexible and change according to the incentives provided by a specific product or contract); and 3. The method of using a ranking system to determine the relative importance of cost, product support, performance, and schedule is open to criticism, for such a system did not permit a respondent to indicate that some or all of the elements were of equal importance to him. Regardless of the inherent weaknesses of the survey, the data permitted a meaningful statistical analysis of design attitudes.

At the heart of the data analysis was the formulation for each subsample of a null hypothesis, H_o, and an alternative hypothesis, H_1. The alternative hypothesis, H_1, in all cases was the operational statement (i.e., the statement believed to be true before any statistical test was applied). By forming a null hypothesis and an alternative hypothesis, it was possible to determine the significance level of a statistical test. This significance level allows one to state the probability of rejecting H_o, in favor of H_1, when H_o is in fact true (i.e., the probability of making a Type I error). Or put in different terms: The significance level gives the probability that the operational statement, H_1, is false. Chapter III discusses the statistical analysis program in detail.

III. DATA ANALYSIS

Three hundred and seventy questionnaires (ten questionnaires to each of thirty-seven companies) were distributed. A summary of the response to the questionnaire is shown in Figure 1.

The data from each questionnaire was directly punched upon a standard eighty column IBM card. This was done in order to be able to use an available computer program, Statistical Package of the Social Sciences (SPSS), for the generation of the necessary subsample histograms and Kendall rank correlation coefficients.

Questionnaires mailed	370		
Returned as undeliverable	0		
Questionnaires delivered		370	
No response		140	
Completed and returned			230
Response rate	62.2%		
Responses not incorporated in survey due to time limitations			36
Sample size			194

FIGURE 1

QUESTIONNAIRE RESPONSE SUMMARY

Several statistical tests were selected for the analysis of the data. The Kendall coefficient of concordance W, which is applicable when there are n objects that are ranked from 1 to n by m judges, was chosen to determine if there existed a community of preference among the respondents in the ranking of the four elements (i.e., the value of W indicates the degree of agreement among the respondents). With this statistical test and the null hypothesis that there is not a community of preference among the respondents (the alternative hypothesis being that there is a community of preference among the respondents), one is able to use Fischer's z-distribution [Kendall 1962] to determine the associated significance level.

Since the Kendall coefficient of concordance W establishes only that a community of preference exists and not what the actual order of importance is, the Wilcoxon matched-pairs signed-ranks test was used to determine the true order of importance (i.e., the relative importance of cost, product support, performance, and schedule). The Wilcoxon test was selected instead of the sign test, because the Wilcoxon test considers both the direction of the difference between two elements and the magnitude of this difference (e.g., if the Wilcoxon test was used to compare the importance of cost with respect to product support, the case where cost was ranked first and product support was ranked fourth would carry more weight than the case where cost was ranked first and product support was ranked second). The Wilcoxon test was used on each possible combination of the four elements (i.e., cost-product support, cost-performance, cost-schedule, product support-performance, product support-schedule, and performance-schedule). With this statistical test and the null hypothesis that element one was considered by the respondents to be more important than element two (the alternative hypothesis being that element two was

considered to be more important than element one), it is possible to obtain an associated significance level with the use of the normal distribution. The use of the normal distribution is justified when N, the sample size, is larger than twenty-five, for the normal distribution is then an excellent approximation of the actual distribution. For all cases included in the analysis, N was greater than twenty-five. By knowing the significance level associated with each of the six combinations, one was able to infer the order of importance among the four elements [Siegel 1956].

The contingency coefficient C, which gives a measure of the association, or relationship, between two distributions of any shape, was chosen to ascertain if product support is considered to have the same importance regardless of whether the product is designed for military, industrial, or consumer use. With this statistical test and the null hypothesis that the importance of product support is independent of the customer for whom the product is designed (the alternative hypothesis being that the importance of product support is not independent of the customer for whom the product is designed), one is able to use the Chi-square distribution to determine a level of significance [Siegel 1956].

The Kendall rank correlation coefficient tau was used as the statistical test to determine if there existed an association between work experience or formal education and the importance attached to product support by military product design personnel. This coefficient is applicable when both variables under study are ranked in two ordered series. With this statistical test and the null hypothesis that work experience has no association with the importance attached to product support by military product design personnel (the alternative hypothesis being that work experience has an association with the importance attached to product support), one is able to calculate a level of significance by using the

normal distribution. The normal distribution may be used to determine a level of significance, for it is an excellent approximation of the actual distribution of tau when N, the sample size, is greater than or equal to eight. This was true for all cases analyzed.

The analysis of the data with the four statistical tests just described was accomplished by taking a restricted sample, a subsample, from the test sample of one hundred and ninety-four cases.

The particular subsample was determined by the hypothesis that was to be tested. The data analysis program consisted of the following:

1. A subsample containing all those respondents who were then employed within the design community and who had had experience in the design of <u>military</u> products was formed. The histograms for this subsample are contained in Appendix C. The Kendall coefficient of concordance W was used on this subsample to determine whether this subsample displayed a community of preference in the ranking of cost, product support, performance, and schedule. The Wilcoxon matched-pairs signed-ranks test was then employed and an actual order of importance was determined.

2. With a subsample made up of all those respondents who were then employed in a design related field and who had had experience in the design of <u>industrial</u> products, the same statistical procedure as outlined in 1 was used to determine an actual order of importance of the elements in the design of <u>industrial</u> products. The histograms for this subsample are given in Appendix D.

3. A subsample comprised of all respondents who were then employed within the design community and who had had experience in the design of <u>consumer</u> products was formed. With the procedure outlined in 1 an actual order of importance of the elements in the design of <u>consumer</u> products was ascertained. The histograms for this subsample are contained in Appendix E.

4. A subsample containing all those respondents who were then employed in a design related field and who had had experience only in the design of military products (i.e., no experience in the design of either industrial or consumer products) was formed. The histograms for this subsample are contained in Appendix F. As outlined in 1, the actual order of importance associated with this subsample was determined. By comparing this order of importance with the order of importance determined for the subsample specified in 1, it was possible to form an opinion on whether experience in the design of either industrial or consumer products effected the order of importance exhibited for military product design.

5. Using the subsamples specified in 1, 2, and 3, the contingency coefficient C was applied to determine if product support was considered to be of the same importance regardless of the customer for whom the product was designed.

6. With the subsample specified in 1, the Kendall rank correlation coefficient tau was used to determine if there existed a relationship between either work experience or formal education and the importance attached to product support by a respondent.

7. In order to determine if a respondent's position in the design community (i.e., manager, designer, or combination manager and designer) effected his order of importance, the subsample in 1 was divided further into three more subsamples: one containing managers only, one containing designers only, and one containing combination managers and designers only. The procedure outlined in 1 was then used to determine if in fact a respondent's position influenced his order of importance. The histograms for these subsamples are contained in Appendices G, H, and I.

IV. RESULTS

In the determination of all orders of importance a level of significance equal to .25 was used (i.e., if the level of significance was greater than or equal to .25 the two elements were considered to be of equal importance.

For the subsample comprised of all those respondents who were then employed in a design position and who had had military product design experience, it was determined that a definite community of preference existed with W = .45012 at a level of significance of .01. The six combinations formed with cost, product support, performance, and schedule yielded the following information:

a. Cost was considered to be more important than product support at a significance level of .023.

b. Performance was considered to be more important than cost at a significance level of .01.

c. Cost was considered to be more important than schedule at a significance level of .078.

d. Performance was considered to be more important than product support at a significance level of .01.

e. Product support was considered to be more important than schedule at a significance level of .44.

f. Performance was considered to be more important than schedule at a significance level of .01.

From the above information, it was inferred that the order of importance in the design of military products was: 1. Performance, 2. Cost, 3. A tie between Schedule and Product Support.

For the subsample made up of all those respondents who were then employed in a design related field and who had had experience in the design of <u>industrial</u> products, it was determined that a definite order of importance existed with W = .49055 at a level of significance of .01. The six combinations formed with cost, product support, performance, and schedule yielded the following information:

a. Cost was considered to be more important than product support at a significance level of .01.

b. Performance was considered to be more important than cost at a significance level of .01.

c. Cost was considered to be more important than schedule at a significance level of .01.

d. Performance was considered to be more important than product support at a significance level of .01.

e. Product support was considered to be more important than schedule at a significance level of .01.

f. Performance was considered to be more important than schedule at a significance level of .01.

From the above information, the following order of importance in the design of <u>industrial</u> products was determined: 1. Performance, 2. Cost, 3. Product Support, 4. Schedule.

For the subsample comprised of all respondents who were then employed within the design community and who had had experience in the design of <u>consumer</u> products, it was determined that a definite community of preference existed with W = .55625 at a significance level of .01. The six combinations of cost, product support, performance, and schedule yielded the following information:

a. Cost was considered to be more important than product support at a significance level of .01.

b. Performance was considered to be more important than cost at a significance level of .013.

c. Cost was considered to be more important than schedule at a significance level of .01.

d. Performance was considered to be more important than product support at a significance level of .01.

e. Product support was considered to be more important than schedule at a significance level of .202.

f. Performance was considered to be more important than schedule at a significance level of .01.

From the above information, it was inferred that the order of importance in the design of consumer products was: 1. Performance, 2. Cost, 3. Product Support, 4. Schedule.

For the subsample consisting of those respondents who were employed in a design position and whose only design experience was with military products, it was determined that a definite order of preference existed with W = .49408 at a significance level of .01. The six combinations formed with cost, performance, product support, and schedule yielded the following information:

a. Cost was considered to be more important than product support at a significance level of .02.

b. Performance was considered to be more important than cost at a significance level of .01.

c. Cost was considered to be more important than schedule at a significance level of .165.

d. Performance was considered to be more important than product support at a significance level of .01.

e. Schedule was considered to be more important than product support at a significance level of .22.

f. Performance was considered to be more important than schedule at a significance level of .01.

From the above information, the following order of importance was determined: 1. Performance, 2. Cost, 3. Schedule, 4. Product Support.

The contingency coefficient C test yielded the following: 1. There existed a strong relationship between the importance attached to product support in the design of military products and the importance attached to product support in the design of industrial products (i.e., C = .226 at a significance level of .01); and 2. There existed a strong relationship between the importance attached to product support in the design of military products and the importance attached to product support in the design of consumer products (i.e., C = .257 at a significance level of .01).

The subsample comprised of all those respondents who were then employed in a design position and who had had military product design experience yielded the following information after the Kendall rank correlation coefficient was applied:

a. No significant relationship existed between work experience and the importance attached to product support by a respondent.

b. No significant relationship existed between formal education and the importance attached by a respondent to product support.

For the subsample containing those respondents who were then employed as a design manager and who had had experience in military product design, a definite community of preference existed with W = .39887 at a significance level of .01. The six combinations formed with cost, product support, performance, and schedule yielded the following information:

a. Performance was considered to be more important than cost at a significance level of .01.

b. Cost was considered to be more important than product support at a significance level of .074.

c. Cost was considered to be more important than schedule at a significance level of .05.

d. Performance was considered to be more important than product support at a significance level of .01.

e. Schedule was considered to be more important than product support at a significance level of .33.

f. Performance was considered to be more important than schedule at a significance level of .01.

From the above information, the following order of importance for managers of military product design was determined: 1. Performance, 2. Cost, 3. A tie between Product Support and Schedule with Schedule slightly more important.

For the subsample comprised of those respondents who were then employed as designers and who had had experience with the design of military products, a definite community of preference existed with W = .54498 at a significance level of .01. The six combinations of cost, product support, performance, and schedule yielded the following information:

a. Product support was considered to be more important than cost at a significance level of .093.

b. Performance was considered to be more important than cost at a significance level of .01.

c. Schedule was considered to be more important than cost at a significance level of .337.

d. Performance was considered to be more important than product support at a significance level of .01.

e. Product support was considered to be more important than schedule at a significance level of .136.

f. Performance was considered to be more important than schedule at a significance level of .01.

From the above information, the following order of importance for designers in the design of military products was inferred: 1. Performance, 2. Product Support, 3. A tie between Cost and Schedule with Schedule being slightly more important.

For the subsample made up of those respondents who were then employed as a <u>combination manager and designer</u> and who had had experience in the design of military products, a definite community of preference existed with $W = .47629$ at a significance level of .01. The six combinations of cost, product support, performance, and schedule yielded the following information:

a. Cost was considered to be more important than product support at a significance level of .01.

b. Performance was considered to be more important than cost at a significance level of .01.

c. Cost was considered to be more important than schedule at a significance level of .15.

d. Performance was considered to be more important than product support at a significance level of .01.

e. Schedule was considered to be more important than product support at a significance level of .15.

f. Performance was considered to be more important than schedule at a significance level of .01.

From the above information, the following order of importance for combination managers and designers in the design of military products was determined: 1. Performance, 2. Cost, 3. Schedule, 4. Product Support.

V. CONCLUSIONS AND RECOMMENDATIONS

The results of the data analysis program partially supported the hypothesis of the study. Personnel engaged in the design of military products did in fact view both performance and production cost as being more important than product support. The exception to the hypothesis was that product support and schedule were considered to be of equal importance.

The results also gave the following indications: 1. Product support is more important in the design of industrial or consumer products than it is in the design of military products. This was borne out by the fact that product support was third in the order of importance for both industrial and consumer product design, but was only tied for third in the order of importance for military product design. Additionally, those respondents whose only design experience had been with military products had product support a definite fourth in their order of importance; and 2. Experience in the design of industrial or consumer products appeared to increase the importance of product support in the design of military products.

The classification of design personnel into the three categories of manager, designer, and combination manager and designer yielded the expected result that respondents in a management position gave more importance to production cost than did designers. Designers considered product support to be second only to performance in their order of importance.

There was no relationship between either work experience of formal education and the respondent's attitude toward product support.

In the view of the author, the study results support the contention that product support has significantly less importance than either performance or production cost in influencing product design. Therefore, it leads one to conclude that the Navy's stress on product support's influence on design was ineffective at the time of this study. The "why" was not addressed in this paper and is a recommended area for future study.

Regardless of the "why," it is recommended that the Navy give immediate consideration to two areas in order to increase the importance of product support considerations in the design of a weapon system:

-Contracts be structured to include profit incentives for product support.

-Contract administration activities be organized to insure incorporation of product support considerations into the design.

APPENDIX A

Design Attitude Questionnaire

1. General classification of present design position.

   ☐ manager ☐ designer ☐ combination of manager and designer ☐ not applicable

2. Years employed as a design engineer.

   ☐ 0-1 ☐ 1-5 ☐ 5-10 ☐ more than 10

3. Years employed in a technical field outside of design engineering.

   ☐ 0-1 ☐ 1-5 ☐ 5-10 ☐ more than 10

4. Years employed in the management of design.

   ☐ 0-1 ☐ 1-5 ☐ 5-10 ☐ more than 10

5. Degrees held in management or business.

   ☐ none ☐ bachelor ☐ master ☐ doctorate

6. Degrees held in engineering.

   ☐ none ☐ bachelor ☐ master ☐ doctorate

7. Degrees held in scientific fields other than engineering.

   ☐ none ☐ bachelor ☐ master ☐ doctorate

8. Have you had experience in the design of military products?

   ☐ yes ☐ no

9. Have you had experience in the design of industrial products?

   ☐ yes ☐ no

10. Have you had experience in the design of consumer products?

    ☐ yes ☐ no

Questions 11, 12, & 13 require the ranking of four elements. In this ranking use 1, 2, 3, or 4 with 1 indicating the item of greatest <u>INFLUENCE</u> and 4 the item of least <u>INFLUENCE</u>. Use each number only once for each question.

Use the following definitions for the elements in questions 11, 12, & 13.

COST - The direct costs (labor & material) required for the manufacture of a product.

PRODUCT SUPPORT - The ease and economy with which a product can be repaired or maintained.

PERFORMANCE - The degree to which a product meets or exceeds specifications.

SCHEDULE - The time allotted to complete the design of a product.

11. In the design of a product to be used primarily by the military, how would rank the following items?

    _____ COST _____ PRODUCT SUPPORT _____ PERFORMANCE _____ SCHEDULE

12. In the design of a product to be used primarily by industry, how would you rank the following items?
____ COST ____ PRODUCT SUPPORT ____ PERFORMANCE ____ SCHEDULE

13. In the design of a product to be used primarily by consumers, how would you rank the following items?
____ COST ____ PRODUCT SUPPORT ____ PERFORMANCE ____ SCHEDULE

APPENDIX B

Questionnaire Cover Letter

Dear Sir,

The success of a system or a product is determined to a large extent by the adequacy of its design which in turn is assumed to be influenced by the attitudes and background of the design manager and design engineer. I desire to gather data in this area with the aid of a short questionnaire to determine if a more extensive survey would be justified.

The accuracy and validity of the research is dependent on questionnaire answers that are free of biasing forces. For this reason explanatory information is not included in this letter or on the questionnaire.

I do not desire to impose an administrative burden on your company. However, a response to the subject questionnaire may provide a significant contribution to the Navy and to your company as well. A summary of the results of this project will gladly be sent to your address if you indicate such a desire.

Subject to your concurrence, it is requested that the enclosed questionnaires be randomly distributed to and completed by design managers and design engineers of your company, and then return anonymously by them in the enclosed self-addressed envelopes.

APPENDIX C

Histograms for Respondents with Experience in the Design of Military Products

Rank of Cost in Military Product Design

```
    I
1.  ******* (  13)  8.0 PCT
    I
    I
2.  *************************** (  53)  32.5 PCT
    I
    I
3.  ************************** (  51)  31.3 PCT
    I
    I
4.  *********************** (  46)  28.2 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0   10   20   30   40   50   60   70   80   90  100
    Frequency
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Valid observations - 163

Rank of Product Support in Military Product Design

```
    I
1.  ** (   1)  0.6 PCT
    I
    I
2.  **************************** (  56)  34.4 PCT
    I
    I
3.  *********************** (  46)  28.2 PCT
    I
    I
4.  ****************************** (  60)  36.8 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0   10   20   30   40   50   60   70   80   90  100
    Frequency
```

Valid observations - 163

Rank of Performance in Military Product Design

```
     I
1.   ************************************ ( 144)  88.3 PCT
     I
     I
2.   ** (    8)  4.9 PCT
     I
     I
3.   ** (    7)  4.3 PCT
     I
     I
4.   * (    4)  2.5 PCT
     I
     I....I....I....I....I....I....I....I....I....I....I
     0    20   40   60   80   100  120  140  160  180  200
     Frequency
```

Valid observations - 163

Rank of Schedule in Military Product Design

```
     I
1.   *** (    5)  3.1 PCT
     I
     I
2.   *********************** (  46)  28.2 PCT
     I
     I
3.   ****************************** (  59)  36.2 PCT
     I
     I
4.   *************************** (  53)  32.5 PCT
     I
     I....I....I....I....I....I....I....I....I....I....I
     0    10   20   30   40   50   60   70   80   90   100
     Frequency
```

Valid observations - 163

APPENDIX D

Histograms for Respondents with Experience in the Design of Industrial Products

Rank of Cost in Industrial Product Design

```
    I
1.  **************** (  31)  23.1 PCT
    I
    I
2.  ****************************** (  59)  44.0 PCT
    I
    I
3.  *************** (  30)  22.4 PCT
    I
    I
4.  ******* (  14)  10.4 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0   10   20   30   40   50   60   70   80   90   100
    Frequency
```

Valid observations - 134

Rank of Product Support in Industrial Product Design

```
    I
1.  ***** (   9)  6.7 PCT
    I
    I
2.  ************** (  28)  20.9 PCT
    I
    I
3.  ***************************** (  58)  43.3 PCT
    I
    I
4.  ******************** (  39)  29.1 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0   10   20   30   40   50   60   70   80   90   100
    Frequency
```

Valid observations - 134

Rank of Performance in Industrial Product Design

```
    I
1.  ********************************************** (  91)  67.9 PCT
    I
    I
2.  ***************** (  34)  25.4 PCT
    I
    I
3.  ***** (   9)  6.7 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0    10   20   30   40   50   60   70   80   90   100
    Frequency
```

Valid observations - 134

Rank of Schedule in Industrial Product Design

```
    I
1.  ** (   3)  2.2 PCT
    I
    I
2.  ******* (  13)  9.7 PCT
    I
    I
3.  ******************* (  37)  27.6 PCT
    I
    I
4.  ***************************************** (  81)  60.4 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0    10   20   30   40   50   60   70   80   90   100
    Frequency
```

Valid observations - 134

APPENDIX E

Histograms for Respondents with Experience in the Design of Consumer Products

<u>Rank of Cost in Consumer Product Design</u>

```
    I
1.  ********************** (  44)  61.1 PCT
    I
    I
2.  ************ (  23)  31.9 PCT
    I
    I
3.  *** (    5)  7.0 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0    10   20   30   40   50   60   70   80   90   100
    Frequency
```

Valid observations - 72

<u>Rank of Product Support in Consumer Product Design</u>

```
    I
1.  * (    1)  1.4 PCT
    I
    I
2.  **** (    7)  9.7 PCT
    I
    I
3.  ****************** (  35)  48.6 PCT
    I
    I
4.  *************** (  29)  40.3 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0    10   20   30   40   50   60   70   80   90   100
    Frequency
```

Valid observations - 72

Rank of Performance in Consumer Product Design

```
    I
1.  ************* (  26)  36.1 PCT
    I
    I
2.  ***************** (  33)  45.8 PCT
    I
    I
3.  ****** (  12)  16.7 PCT
    I
    I
4.  * (    1)  1.4 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0    10   20   30   40   50   60   70   80   90   100
    Frequency
```

Valid observations - 72

Rank of Schedule in Consumer Product Design

```
    I
1.  * (   1)  1.4 PCT
    I
    I
2.  ***** (   9)  12.5 PCT
    I
    I
3.  ********** (  20)  27.8 PCT
    I
    I
4.  ********************* (  42)  58.3 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0    10   20   30   40   50   60   70   80   90   100
    Frequency
```

Valid observations - 72

APPENDIX F

Histograms for Respondents with Experience only in the Design of Military Products

Rank of Cost in Military Product Design

```
     I
1.   *************** (   3)  11.5 PCT
     I
     I
2.   ************************************************** (  10)  38.5 PCT
     I
     I
3.   *********************************** (   7)  26.9 PCT
     I
     I
4.   ****************************** (   6)  23.1 PCT
     I
     I....I....I....I....I....I....I....I....I....I....I
     0    1    2    3    4    5    6    7    8    9    10
     Frequency
```

Valid observations - 26

Rank of Product Support in Military Product Design

```
     I
2.   *************** (   6)  23.1 PCT
     I
     I
3.   ******************** (   8)  30.8 PCT
     I
     I
4.   ****************************** (  12)  46.1 PCT
     I
     I....I....I....I....I....I....I....I....I....I....I
     0    2    4    6    8    10   12   14   16   18   20
     Frequency
```

Valid observations - 26

Rank of Performance in Military Product Design

```
    I
1.  *********************** (  23)  88.5 PCT
    I
    I
2.  ** (   2)  7.7 PCT
    I
    I
4.  * (   1)  3.8 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0    5    10   15   20   25   30   35   40   45   50
    Frequency
```

Valid observations - 26

Rank of Schedule in Military Product Design

```
    I
2.  ******************** (   8)  30.8 PCT
    I
    I
3.  *************************** (  11)  42.3 PCT
    I
    I
4.  ***************** (   7)  26.9 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0    2    4    6    8    10   12   14   16   18   20
    Frequency
```

Valid observations - 26

APPENDIX G

Histograms for Respondents with Experience in the Design of Military Products and a Position as a Manager

<u>Rank of Cost in Military Product Design</u>

```
    I
1.  ******** (   8)  13.1 PCT
    I
    I
2.  ***************** (  17)  27.9 PCT
    I
    I
3.  ********************* (  21)  34.4 PCT
    I
    I
4.  *************** (  15)  24.6 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0    5    10   15   20   25   30   35   40   45   50
    Frequency
```

Valid observation - 61

<u>Rank of Product Support in Military Product Design</u>

```
    I
2.  ************* (  23)  37.7 PCT
    I
    I
3.  ******** (  16)  26.2 PCT
    I
    I
4.  *********** (  22)  36.1 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0    5    10   15   20   25   30   35   40   45   50
    Frequency
```

Valid observations - 61

Rank of Performance in Military Product Design

```
    I
1.  ************************** (   51)  83.6 PCT
    I
    I
2.  *** (   5)  8.2 PCT
    I
    I
3.  ** (   2)  3.3 PCT
    I
    I
4.  ** (   3)  4.9 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0    10   20   30   40   50   60   70   80   90   100
    Frequency
```

Valid observations - 61

Rank of Schedule in Military Product Design

```
    I
1.  ** (   2)  3.3 PCT
    I
    I
2.  **************** (  16)  26.2 PCT
    I
    I
3.  ********************** (  22)  36.1 PCT
    I
    I
4.  ********************* (  21)  34.4 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0    5    10   15   20   25   30   35   40   45   50
    Frequency
```

Valid observations - 61

APPENDIX H

Histograms for Respondents with Experience in the Design of Military Products and a Position as a Designer

<u>Rank of Cost in Military Product Design</u>

```
    I
1.  *** (   1)  2.9 PCT
    I
    I
2.  ******************** (   8)  23.5 PCT
    I
    I
3.  **************************** (  11)  32.4 PCT
    I
    I
4.  *********************************** (  14)  41.2 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0    2    4    6    8    10   12   14   16   18   20
    Frequency
```

Valid observations - 34

<u>Rank of Product Support in Military Product Design</u>

```
    I
2.  ************************************** (  15)  44.1 PCT
    I
    I
3.  ****************************** (  12)  35.3 PCT
    I
    I
4.  ****************** (   7)  20.6 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0    2    4    6    8    10   12   14   16   18   20
    Frequency
```

Valid observations - 34

Rank of Performance in Military Product Design

```
     I
1.   ******************************** (  32)  94.1 PCT
     I
     I
2.   ** (   1)  2:95 PCT
     I
     I
3.   ** (   1)  2.95 PCT
     I
     I....I....I....I....I....I....I....I....I....I....I
     0    5    10   15   20   25   30   35   40   45   50
     Frequency
```

Valid observations - 34

Rank of Schedule in Military Product Design

```
     I
1.   *** (   1)  3.0 PCT
     I
     I
2.   ************************* (  10)  29.4 PCT
     I
     I
3.   ************************* (  10)  29.4 PCT
     I
     I
4.   ********************************* (  13)  38.2 PCT
     I
     I....I....I....I....I....I....I....I....I....I....I
     0    2    4    6    8    10   12   14   16   18   20
     Frequency
```

Valid observations - 34

APPENDIX I

Histograms for Respondents with Experience in the Design of Military Products and a Position as a Combination Manager and Designer

Rank of Cost in Military Product Design

```
    I
1.  **** (   4)  5.9 PCT
    I
    I
2.  **************************** (  28)  41.2 PCT
    I
    I
3.  ******************* (  19)  27.9 PCT
    I
    I
4.  ***************** (  17)  25.0 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0    5    10   15   20   25   30   35   40   45   50
    Frequency
```

Valid observations - 68

Rank of Product Support in Military Product Design

```
    I
1.  ** (   1)  1.4 PCT
    I
    I
2.  ****************** (  18)  26.5 PCT
    I
    I
3.  ****************** (  18)  26.5 PCT
    I
    I
4.  ******************************* (  31)  45.6 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0    5    10   15   20   25   30   35   40   45   50
    Frequency
```

Valid observations - 68

Rank of Performance in Military Product Design

```
    I
1.  ******************************* (  61)  89.7 PCT
    I
    I
2.  ** (   2)  2.9 PCT
    I
    I
3.  *** (   4)  5.9 PCT
    I
    I
4.  * (   1)  1.5 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0    10   20   30   40   50   60   70   80   90   100
    Frequency
```

Valid observations - 68

Rank of Schedule in Military Product Design

```
    I
1.  ** (   2)  2.9 PCT
    I
    I
2.  ******************** (  20)  29.4 PCT
    I
    I
3.  *************************** (  27)  39.7 PCT
    I
    I
4.  ******************* (  19)  28.0 PCT
    I
    I....I....I....I....I....I....I....I....I....I....I
    0    5    10   15   20   25   30   35   40   45   50
    Frequency
```

Valid observations - 68

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It is hypothesized that in the aggregate design managers and engineers do not view product support as being of the same importance as production cost, performance, and schedule in their design of military systems/equipments. The results of a study to determine if this is true are set forth, and the implications of the results are discussed as they relate to the Navy's policy on Integrated Logistic Support.

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